CLAIMS

What is claimed:

[c01] An electroslag-cold hearth system for refining or producing a metal, comprising the following elements:

a) at least one cold hearth vessel for melting and holding a pool of molten liquid metal;

b) a liquid slag layer situated partially above the cold hearth vessel;

c) at least one source of the metal positioned above the liquid slag layer;

d) an ingot mold for receiving molten metal from the pool of molten metal, laterally off-set from the source of the metal, and situated below a portion of the slag layer;

e) at least one power supply for electrically heating the slag layer; and

f) a flow-over dam, separating the cold hearth vessel from the ingot mold.

[c02] The electroslag-cold hearth system of claim 1, wherein the source of metal comprises a consumable electrode of the metal.

[c03] The system of claim 2, further including means for advancing the consumable electrode toward and into contact with the slag layer.

[c04] The system of claim 1, wherein the source of metal comprises at least one of metal revert and virgin metal material.

[c05] The system of claim 1, wherein the cold hearth vessel comprises a liquid-cooled reservoir.

[c06] The system of claim 5, wherein the cold hearth vessel is a water-cooled metal reservoir.

[c07] The system of claim 1, wherein the liquid slag layer comprises at least one material selected from the group consisting of calcium metal, calcium halides, calcium oxide, and mixtures thereof.

[c08] The system of claim 1, wherein the flow-over dam comprises a wall which permits the flow of liquid metal into the ingot mold, but substantially prevents the flow of inclusions into the ingot mold.

[c09] The system of claim 8, wherein the wall comprises a metallic material, and is liquid-cooled.

[c10] The system of claim 1, wherein the power supply comprises an electric supply means adapted to supply current to the consumable electrode and through the liquid slag layer in the cold hearth vessel, thereby keeping the slag molten, while melting the end of the electrode which is in contact with the slag.

[c11] The system of claim 1, further comprising at least one non-consumable electrode which is in contact with the slag layer.

[c12] The system of claim 11, including means for supplying current to the slag layer through the non-consumable electrode.

[c13] The system of claim 12, wherein the means for supplying current comprises a second power supply.

[c14] The system of claim 11, wherein the non-consumable electrode is in the shape of a frame.

[c15] The system of claim 14, wherein a portion of the frame surrounds a lower end of the consumable electrode.

[c16] The system of claim 11, wherein the non-consumable electrode comprises an upper section of the cold hearth vessel and the ingot mold, separated from the lower section of the cold hearth vessel and the ingot mold by an insulator.

[c17] The system of claim 11, wherein the non-consumable electrode is mounted on a structure which allows it to move vertically, relative to the slag layer.

[c18] The system of claim 11, wherein the non-consumable electrode comprises an electrically conductive material.

[c19] The system of claim 18, wherein the electrically conductive material comprises graphite or copper.

[c20] The system of claim 18, wherein the electrically conductive material is covered or capped by a refractory metal.

[c21] The system of claim 1, wherein the metal comprises at least one element selected from the group consisting of titanium, nickel, aluminum, tin, antimony, beryllium, boron, gallium, molybdenum, niobium, tantalum,

thorium, zirconium, vanadium, iridium, osmium, rhenium, uranium, and rare earth elements.

[c22] The system of claim 1, wherein the metal comprises titanium or a titanium alloy.

[c23] The system of claim 22, wherein the alloy comprises titanium and at least one metal selected from the group consisting of aluminum and vanadium.

[c24] A system according to claim 1, for electrolytically producing a metal, wherein at least a portion of the metal source of component (c) comprises at least one compound from which the metal can be electrochemically extracted.

[c25] The system of claim 24, wherein the portion of the metal source comprises at least one salt of the desired metal.

[c26] The system of claim 25, wherein the metal is titanium or a titanium alloy, and the metal source comprises at least one titanium salt.

[c27] The system of claim 24, wherein the portion of the metal source is in the liquid or gaseous state, and a gas/liquid source for the portion of the metal source communicates with the liquid slag layer through a passageway.

[c28] The system of claim 24, further including at least one additional metal source for producing the desired metal.

[c29] The system of claim 28, wherein the additional metal source comprises solid metal material.

[c30] The system of claim 29, wherein the solid metal material comprises at least one of metal revert and virgin metal material.

[c31] The system of claim 28, wherein the additional metal source comprises a consumable electrode of the desired metal.

[c32] An electroslag-cold hearth system for refining or producing a metal or metal alloy, comprising at least one cold hearth vessel capable of holding a pool of liquid metal and an overlying slag layer; and an ingot mold which communicates with the cold hearth through a flow-over dam which allows the liquid metal to flow from the hearth to the ingot mold while substantially preventing the flow of inclusions to the ingot mold, wherein a source of raw metal situated above the cold hearth is laterally off-set from the ingot mold.

[c33] An electroslag-cold hearth system for refining titanium or a titanium alloy, comprising the following elements:

(I) a cold hearth vessel for melting and holding a pool of molten liquid titanium or titanium alloy;

(II) a calcium-based liquid slag layer situated partially above the cold hearth vessel;

(III) a consumable electrode of the titanium or titanium alloy, positioned above the liquid slag layer;

(IV) an ingot mold for receiving the molten titanium or titanium alloy, laterally off-set from the consumable electrode, and situated below a portion of the slag layer;

(V) a power supply for electrically heating the slag layer;

(VI) a flow-over dam, separating the cold hearth vessel from the ingot mold; and

(VII) a non-consumable, electrically conductive electrode, in contact with the slag layer, and capable of providing additional thermal energy to the slag layer.

[c34] An electroslag-cold hearth system for electrolytically producing titanium or a titanium alloy, comprising the following elements:

(A) a cold hearth vessel for melting and holding a pool of molten liquid titanium or titanium alloy;

(B) a calcium-based liquid slag layer situated partially above the cold hearth vessel;

(C) a source for containing at least one titanium salt in liquid or gaseous form, wherein the salt can be electrochemically reduced to the titanium or titanium alloy when introduced into the liquid slag layer;

(D) an ingot mold for receiving the molten titanium or titanium alloy, laterally off-set from the cold hearth vessel, and communicating therewith;

(E) a power supply for electrically heating the slag layer;

(F) a flow-over dam, separating the cold hearth vessel from the ingot mold; and

(G) a non-consumable, electrically conductive electrode, in contact with the slag layer, and capable of providing additional thermal energy to the slag layer.

[c35] The electroslag-cold hearth system of claim 34, further comprising a feed system for directing titanium-based revert material or virgin titanium material to the slag layer.

[c36] The electroslag-cold hearth system of claim 34, further comprising a consumable electrode formed of titanium or titanium alloy, and positioned so that it can be lowered into contact with the slag layer, to allow for the refining of the titanium or titanium alloy while additional titanium or titanium alloy material is being electrolytically produced, in accordance with element (C).

[c37] A method of refining a metal in an electroslag-cold hearth system, comprising the following steps:

(I) melting a source of the metal to form a pool of molten metal, by contacting the source with a molten slag layer contained in a cold hearth vessel;

(II) directing the pool of molten metal from the cold hearth vessel, over a flow-over dam, to an ingot mold which is laterally off-set from the source of the metal; and

(III) cooling and solidifying the metal.

[c38] The method of claim 37, wherein the source of the metal is a consumable electrode.

[c39] The method of claim 37, wherein the source of metal comprises at least one of metal revert and virgin metal material.

[c40] The method of claim 37, wherein the flow-over dam prevents the movement of substantially all inclusions from the cold hearth vessel to the ingot mold.

[c41] The method of claim 37, wherein the source of the metal is a consumable electrode, and the slag is maintained in a molten state by the action of electric current flowing from a power source, through the consumable electrode, and to the slag.

[c42] The method of claim 41, wherein the slag is also heated by at least one additional energy means.

[c43] The method of claim 42, wherein the additional energy means is an electric supply means adapted to supply electric current through the cold hearth vessel to the slag layer.

[c44] The method of claim 42, wherein the electric current for the additional energy means is supplied to the slag layer through a non-consumable electrode which is in contact with the slag layer.

[c45] The method of claim 44, wherein the non-consumable electrode is mounted on a structure which allows it to move vertically, relative to the slag layer, so that the electrical impedance of the electroslag-cold hearth system can be adjusted by such vertical movement.

[c46] The method of claim 37, wherein the metal being refined comprises at least one element selected from the group consisting of titanium, nickel, aluminum, tin, antimony, beryllium, boron, gallium, molybdenum, niobium, tantalum, thorium, zirconium, vanadium, iridium, osmium, rhenium, uranium, and rare earth elements.

[c47] A method for producing a metal from at least one raw material source of the metal, comprising the following steps:

(A) electrolytically reacting the metal source with a composition which comprises molten electrolyte in a cold hearth vessel, so as

to extract the metal from the metal source, wherein the extracted metal resides in the cold hearth beneath the molten electrolyte; and then

(B) directing the molten metal from the cold hearth vessel, over a flow-over dam, to an ingot mold which is laterally off-set from the source of the metal.

[c48] The method of claim 47, further comprising the step of cooling and solidifying the molten metal in the ingot mold, to produce an ingot of the metal.

[c49] The method of claim 47, further comprising the step of refining an additional metal source, wherein the additional metal source is in the form of an ingot which is melted in the molten electrolyte, and wherein the refining of the additional metal source can be carried out simultaneously with production of a metal according to steps (A) and (B).